REMARKS

Claim 3 and new claims 7-12 are now in this application. Claims 1, 2 and 4-6 are cancelled. Claim 3 is rejected and is amended herein to clarify the invention, to broaden language as deemed appropriate and to address matters of form unrelated to substantive patentability issues.

Restriction Requirement

In view of the earlier restriction requirement, non-elected claims 1, 2 and 4-6 are canceled without prejudice to filing a divisional application directed to the subject matter of these claims.

Drawings

In response to the objection to the drawings, submitted herewith is proposed new Fig. 7 in which dentures in accordance with the invention, i.e., dentures obtained by the pulsed electron beam method in accordance with the invention, are shown. The specification has been amended to refer to new Fig. 7. As such dentures were discussed in the original specification, no new matter is added by the presentation of Fig. 7 or the corresponding amendments to the specification.

Claim Rejections-35 U.S.C. §112

Claim 3 is amended to remove the informality noted by the Examiner and now does not include the phrase "and corrosion resistance modified products".

In view of the change to claim 3, it is respectfully submitted that the Examiner's rejection of claim 3 under 35 U.S.C. §112, second paragraph, has been overcome and should be removed.

Claim Rejections-35 U.S.C. §102

Claim 3 is rejected under 35 U.S.C. §102(b) as being anticipated by the Chiaramonte reference (U.S. Pat. No. 4,108,642), by the Cecconi reference (U.S. Pat. No. 4,995,811) and by the Kirkpatrick reference (U.S. Pat. No. 4,229,232).

Claim 3 is amended to clarify that the claim is directed to metal and/or partial metal dentures adapted to be inserted into a human mouth and provide an appearance of teeth. Also, claim 3 is amended to specify that the dentures comprise an at least partially metal substrate providing the form of the teeth and having at least one polished, amorphous surface obtained by application of pulsed electron beam irradiation.

As discussed in detail in the specification, dentures in accordance with the invention are made by subjecting unpolished dentures to pulsed electron beam treatment which has been found by the inventors to be effective to render the surface of the dentures sufficiently polished to eliminate the requirement of a dental technician having to hand-polish the dentures.

An important advantage obtained by a pulsed electron beam treatment is that the resultant polished surface is amorphous, i.e., lacks distinct crystalline structure.

This provides the dentures with stronger resistance to acids (see page 1, last paragraph of the original specification).

The cited prior art does not disclose dentures having a surface obtained by pulsed electron beam irradiation which surface is rendered polished and amorphous.

Chiaramonte describes dentures made of a metal alloy and which are polished and cleaned ultrasonically in alcohol. Cecconi generally describes finishing and polishing dentures.

The Chiaramonte and Cecconi references do not disclose, teach or suggest that a surface of the dentures is polished and amorphous, such a surface being obtained by pulsed electron beam irradiation, and thus do not disclose an advantage of such an amorphous surface, i.e., improved acid corrosion resistance.

The Kirkpatrick reference describes processing a specimen using pulsed electron beam irradiation. However, claim 3 is now limited to dentures and Kirkpatrick does not disclose the use of the pulsed electron beam treatment to dentures.

In view of changes to claim 3 and the arguments presented above, it is respectfully submitted that the Examiner's rejections of claim 3 have been overcome and should be removed and that the present application is now in condition for allowance.

Applicant respectfully requests a one month extension of time for responding to the Office Action. Please charge the fee of $110 for the extension of time to Deposit Account No. 10-1250.

In light of the foregoing, the application is now believed to be in proper form for allowance of all claims and notice to that effect is earnestly solicited. Please charge any deficiency or credit any overpayment to Deposit Account No. 10-1250.

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enc: Fig. 7

MARKED SPECIFICATION

F-7038 Ser. No. 09/893,138

SURFACE MODIFICATION PROCESS ON METAL DENTURES, PRODUCTS PRODUCED THEREBY, AND THE INCORPORATED SYSTEM THEREOF

FIELD OF THE INVENTION

The present invention relates to full and partial metal dentures having a polished surface.

BACKGROUND OF THE INVENTION

The ~~requirement of~~ need for dentures is ~~meaningless~~ too valuable to detail here. It is also human history to seek better dentures to ~~keep the human~~ maintain a healthy ~~life~~ lifestyle by increasing the pleasure of the table, i.e., the pleasure obtained from eating.

There are some materials ~~to compose the~~ from which dentures are made such as plastics, ceramics, metals and others. Metal or partial metal dentures are dentures made with metal materials, which is [[said]] now thought to be the best materials ~~now~~.

~~The metal~~ Metal materials are roughly classified into three categories, namely, [[of]] Titanium System Alloys, Cobalt System Alloys and Precious System Alloys.

As [[the]] a recent trend, the ~~requirement of~~ Titanium System Alloys are ~~in majority~~ primarily used, while on the other hand, Precious System Alloys are ~~in minor~~ used quite infrequently due to [[its]] their deformation phenomena or heavier weight.

The features of metal and/or partial metal dentures are ~~well fitness~~ that they provide a good fit in the mouth, an immediate reaction [[of]] to hot foods in the

mouth due to [[its]] their high thermal conductivity and [[its]] they are lightweight, at least in the case of Titanium System Alloys.

On the other hand, ~~to fabricate the~~ fabricating metal and/or partial metal dentures requires the ~~long years experience of~~ dental technicians to have a lot of experience and ~~their well-performed~~ skills. Therefore, it takes [[much]] a relatively long time to fabricate [[the]] metal and/or partial metal dentures, and [[it]] they usually ~~highly~~ have high costs.

To fabricate the metal and/or partial metal dentures, there are ~~plenty of~~ several steps ~~as~~ , first melting the alloys ~~melting first~~, then casting the melted alloys in the mold and finally finishing the surface with [[handy]] small, hand-held diamond [[small]] abrasive tools.

After de-molding, the cast metal and/or partial metal dentures are typically finished by a well-experienced dental technician with handy tools, therefore the technician is able to finish one metal and/or partial metal denture in two or three hours or in half day [[in]] at the longest. Moreover, the surface finishing in the process [[are]] is designed to remove the cast skin layer from the metal and/or partial metal dentures and fit the ~~mouth~~ shape of the wearer's mouth ~~from the metal and/or partial metal dentures~~, then the ~~surface~~ surfaces are ~~to be~~ corroded by the acid in the wearer's stomach to change the color from metallic to black

SUMMARY OF THE INVENTION

In ~~the mentioned~~ dentures in accordance with the invention, electron beams in pulsed repetition are bombarded onto the total or entire surface of the substrate of the metal and/or partial metal dentures which provide the form of teeth and are adapted for insertion into a wearer's mouth. The surface of the metal and/or partial metal dentures as [[its]] it is after the cast [[were]] is melted [[and]] is turned into amorphous surface by the pulsed repetition of the electron beams. This eliminates

the time and cost of the processing of the cast metal and/or partial metal dentures with ~~handy~~ diamond tools by a well-experienced dental technician. Due to amorphous metal surface, the electron beam treated surface shows 2 to 5 times stronger resistance against accelerated hydrochloride acid solution.

The invention contributes to ~~reduce~~ a reduction in the time to provide the metal and/or partial metal dentures ~~with~~ to several minutes from hours of fabrication as in the prior art; moreover, its acid corrosion resistance is dramatically increased to enable the dentures to last ~~perform~~ for long years of use.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows the schematic general assembly of a pulsed electron beam system, which was used to modify the surface of the metal and/or partial metal dentures in accordance with the invention.

Fig. 2 indicates a typical operating condition as accelerated voltage and beam current.

Fig. 3 shows the operation data in the pulsed electron beam system [[. In]] in which in the chamber, there exists partial Argon gas in vacuum chamber and the beam irradiated onto the metal and/or partial metal dentures

Fig. 4 shows the visible light reflection ratio from the metal and/or partial metal dentures before and after treatment in accordance with the invention. ~~To make clear the increase of reflection ratio, the inventors apply the silver metal against the light beam wavelength from 300nm to 800nm. Comparing to the untreated sample, the light beam reflection ratio was remarkably increased after the pulsed electron beam bombardment.~~

Fig. 5 shows the X-ray diffraction for samples before and after the pulsed electron irradiation~~, respectively~~. ~~X-ray diffraction result of the sample before irradiation shows the peak points of Titanium Metal. On the other hand, the X-ray~~

~~diffraction after irradiation shows some peak of re-crystallized Titanium Metal. This indicates that the surface of the metal and/or partial metal dentures is turned into semi-amorphous condition.~~

Fig. 6 shows the results of anodic polarization of before and after pulsed electron beam irradiation onto pure Titanium metal ~~dentures. In this case~~ dentures, in which, the counter electrode material is platinum and the solution was 1 Normal Hydrochloride water solution.

Fig. 7 shows metal and/or partial metal dentures in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

The schematic assembly of Pulsed Electron Beam System is shown in the Fig. 1. The vacuum chamber is ~~consisted with~~ made of stainless steel. The original vacuum degree is about 10^{-2} Pa and Argon gas is partially filled into the chamber. The cumulated energy is discharged from the cathode to the collector through a double layer between the cathode plasma and the anode plasma column. For formation of the plasma column, a high current reflected (Penning) discharge in Ar working gas is applied.

The [[said]] pulsed electron beam system has an anode with the shape of a ring or topological similar to it (for example rectangular, polygonal ring structure etc.), which is installed in [[such]] a position where the axis of the ring is parallel to the beam transportation path. This position ~~has~~ provides a benefit of preventing a decrease of beam current caused by collision of electrons on the anode surface.

Detailed processes of electron beam treatment are described as follows. After setting the sample on the sample holder and [[close]] closing the chamber lid, the chamber 1 is evacuated from atmospheric pressure until the initial background pressure is obtained by using a scroll pump 2 for roughing vacuum and turbo

molecular pump 3 for high vacuum evacuation. Then, Ar gas is filled in the chamber 1 and its pressure is adjusted up to a certain pressure between 0.5-3 X 10^{-1} Pa by using a flow control valve 4. After reaching the setting pressure, a pulse guide magnetic field with strength up to 4.4 kOe is created by two external solenoids 5. In Fig. 2, ~~it is shown~~ a typical current pulse of solenoid 14 is shown. During the generation of the magnetic field, a positive pulse high voltage (about 5 kV) with anode pulse current 15 is applied to a ring-shaped anode 6 to obtain an intensive anode-plasma 7 by a reflected Penning discharge method. As another method, anode plasma might be produced simply by arc discharge, but the method would wear out the electrode, which may lead to chamber contamination. Moreover, comparing the consuming current, the arc discharge needs higher current than the present method.

After obtaining high current stage of anode plasma current (generally 20-50 μs after applying voltage on the anode), a negative accelerating voltage pulse 16 with an amplitude below 50 kV and rise time of 5-10 ns is applied to the electron gun cathode 8. An intensive electric field between the cathode and the near-cathode layer of the ionic space charge, can reach to considerable values up to 500 kV/cm and is enough to initiate an explosive electron emission for formation of a dense cathode-plasma 9. The accelerating voltage applied on the anode and cathode is concentrated in a double layer 10 created between the cathode and anode plasmas, where the high current electron beam 11 is formed. The electron beam current density in the double layer is related to the anode plasma ion current density by Langmuir law.

The electron beam accelerated in the double layer 10 is transported through the anode plasma to the beam collector, on which the samples is placed. Owing to the ionic space charge by the anode plasma ions in the present system, the high

current electron beam can be more stable compared to beams in a vacuum. As usually occurred in vacuum-electron beam systems, due to repulsive Coulomb force between the electrons, the electron beam may be scattered to cause a decrease of beam current. In the present electron beam system, the decrease of the beam current can be suppressed by the existence of ions in the anode plasma.

EXAMPLE 1

The metal and/or partial metal dentures 12 are set on the rotating sample holder 13. The beam energy density was 3 J/cm^2. After the electron beam bombardment with 5 pulses repetition, the as-cast metal and/or partial metal dentures show metallic glittering surface and amorphous layer (the dentures being shown in Fig. 7). This indicates that the hand polishing with diamond tools are not required. ~~In case that~~ When the rotating metal holder is thermally insulated with rock wool, the surface ~~is melting~~ melts down further than ~~the~~ expected.

EXAMPLE 2

Reducing the accelerated voltage from 30, 27, 25 kV and the remained partial gas pressure was increased as the irradiated energy is reduced. When the irradiated energy is lower than 0.1 J/cm^2 on the metal and/or partial metal dentures, any surface reaction was not observed even in the case of low melting alloys as Magnesium, Titanium, and high thermal conductive metal as Aluminum.

EXAMPLE 3

~~In case~~ When the pulse repetition exceeds 100 with an energy density of 3 J/cm^2, the metal and/or partial metal dentures are deformed and ~~it lost the fitness to mouth~~ they lose their ability to fit into the wearer's mouth. On the other hand, no

surface modification was observed with pulse repetition over 30 with an energy density of 0.1 J/cm^2.

EXAMPLE 4

After the electron beam irradiation with condition stated in Example 1 (i.e., energy density is 3 J/cm^2, pulse duration is 1.5 μs and pulse repetition is 5 times), the surface of the metal and/or partial metal dentures shows the equivalent reflectance as dentures polished by the dental specialist ~~polished~~ with diamond hand tools. To indicate the reflection ratio numerically, we applied spectroscopy analysis against reflected beam with the beam length range of 300 to 800 nm [[as]] with the ~~result~~ results being shown in Fig. 4.

To make the increase in the reflection ratio clear, the silver metal was applied against the light beam wavelength from 300nm to 800nm. In comparison to an untreated sample, the light beam reflection ratio was remarkably increased after the pulsed electron beam bombardment.

At almost maximum peak wavelength (i.e., 535 nm), the reflection rate after electron beam irradiation was 71% from the metal and/or partial metal dentures. On the other hand, the metal and/or partial metal dentures before the electron beam irradiation ~~shows~~ was 35.5%. In [[the]] this case, the materials of the substrate used for the metal and/or partial metal dentures are an Ag-Pd-Au system alloy.

EXAMPLE 5

To the metal and/or partial metal dentures made with Titanium system alloys, X-ray diffraction is applied to determine the surface crystal phase. The result is shown in Fig. 5 for the before and after electron beam irradiation on the metal and/or partial metal dentures. For the before electron beam irradiation metal

dentures, [[the]] titanium peaks are observed, on the other hand, [[the]] titanium peaks could not be found in the dentures of the after electron beams irradiation except some peaks from re-crystallization. This shows that the surface of metal and/or partial metal dentures after the electron beam irradiation turned into amorphous.

EXAMPLE 6

To determine how the corrosion resistance was modified through the electron beam irradiation, Anodic polarity method was applied on pure Titanium as the result is shown in Fig. 6. Applying <u>the</u> Tafel equation, the corrosion electric current was compared between the after electron beam irradiated and the before electron beam irradiated. This was measured in 1N HC1 water solution.

As the result, the corrosion electric current show 0.03 $\mu A/cm^2$ and 0.01 $\mu A/cm^2$, respectively. This means that the metal and/or partial metal dentures after electron beam irradiation have three times stronger resistance than the non-irradiated metal and/or partial metal dentures.

EXAMPLE 7

The amplitude of the applied voltage to the accelerating gap exceeds than 50 kV. After the pulse repetition exceeds 3, the metal and/or partial metal dentures were ~~thermal~~ <u>thermally</u> deformed though it indicated mirror and amorphous surface.

EXAMPLE 8

The electron beam irradiation was done in <u>a</u> continued mode. ~~In the case~~ <u>For</u> the heat cycle diffusion, heating and rapid cooling [[,]] cannot be done well and <u>a</u> homogeneous amorphous surface could not be obtained.

EXAMPLE 9

Pulse duration was varied and ~~in case~~ when the duration was shorter than 0.5 μs, [[the]] microcracks were observed on the surface of metal and/or partial metal dentures, so the corrosion resistance decreases essentially. ~~And in case,~~ When the duration is over ~~than~~ 10 μs, the non-homogeneous surface could be obtained. This relation is summarized as

$$\tau \approx k \bullet r^2 / a \qquad (1)$$

where

r is an extrapolated penetration depth of the electrons in material,

$a = \lambda / p \bullet c$ is thermal diffusivity,

λ, p, c are thermal conductivity, density, and heat capacity, respectively.

For most [[of]] materials, the value of a belongs [[to]] in the range from 0.06 (for Ti) to 1.12 cm^2/s (for Cu). Concerning the value of r, it belongs [[to]] in the range (at electrons energy 20-40 keV) from 0.5—1.3 μm (for W) to 3.3 -9.3 μm (for Al), correspondingly.

The coefficient k depends on the material properties, namely it is defined by the relation between a and r. To provide a high efficiency of the surface heating, [[from]] on one hand, and to decrease the thermal stresses defined by the temperature gradients in a surface layer [[from]] on the other hand, the value of k is chosen by the following way:

a) for most [[of]] constructive metallic alloys (alloys on the base of Fe, Al, and Ti), the coefficient $k \approx 1 \div 5$.

b) ~~In case of the~~ for materials having high temperature conductivity and [[for]] a small value of penetration depth r (Cu, Mo< W and alloys based on them), the coefficient k should be equal $k \approx 10 \div 50$.

Using [[the]] Eq. 1 and taking into account the limitations of $k_\perp$ one can obtain the range of the beam pulse duration $\tau \approx 0.5 \div 10\ \mu s$.

ABSTRACT OF THE DISCLOSURE

~~A Pulsed Electron Beam System is developed and applied for the surface modification of the metal~~ Metal and/or partial metal dentures having a surface modified by a pulsed electron beam system. The system ~~is consisted with~~ includes an explosive emission cathode, an accelerating gap formed by the cathode and plasma anode, and an electron collector where the metal and/or partial metal dentures are fixed, and placed into a magnetic field. The ~~method can provide a~~ surface of the modified metal and/or partial metal denture ~~surface with~~ has high reflectance [[as]] like a mirror polished surface and high corrosion resistance.